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APPLICATIONS OF DYNAMICS TO PHYSICS AND CHEMISTRY.

Applications of Dynamics to Physics and Chemistry. By J. J. Thomson, M.A., F.R.S., Cavendish Professor of Experimental Physics, Cambridge. (London: Macmillan and Co., 1888.)

THIS is one of the most original books on mathematical physics which has appeared for a long time. Prof. J. J. Thomson has elaborated a method of very wide scope, and has applied it to a large number of problems of very different kinds. A reader of the work must perforce be struck not only with the mathematical ability of the author, but with the wide extent of learning which enables him to illustrate his theme by recent researches in nearly every branch of physics and physical chemistry.

The method employed is so essentially mathematical that it is not easy to describe it without the use of symbols. As, however, it is a matter of considerable importance that those who are studying by means of experiment the phenomena discussed by Prof. Thomson should have some idea as to the progress already made in their theoretical explanation, it may be well to give an account of the general principles which he has used.

In ordinary dynamics it is necessary to specify the positions of the members of a system of bodies of which the movements or mutual actions are under consideration. This is done by means of co-ordinates, which define their positions at a given time with respect to certain given lines or surfaces. If the system is in motion, the values of these quantities change with the time, and thus the co-ordinates may be regarded as possessing velocities.

The difference between the kinetic and potential energies of the system (which is called the Lagrangian function) can be expressed in terms of the co-ordinates and their velocities, and if this is done the magnitude of the force which is acting on the system and tending to increase the value of any particular co-ordinate can be deduced from it. If no such force is acting, it follows that a certain relation between the co-ordinates and their velocities must be satisfied.

This is a perfectly general dynamical method, which could be directly applied to the complex system of atoms and ether by which the physical phenomena displayed by any given body are produced, if it were not for difficulties which Prof. Thomson has attempted, as far as may be, to overcome.

In the first place, the dynamical method presupposes a knowledge of the relative positions of the members of the system, *i.e.* of its geometry, and we cannot at present express "such things as the distributions of electricity and magnetism, for example," in terms of the relative positions or movements of atoms and ether.

In the next place, even when we can express certain physical states in terms of quantities which completely describe all that we can observe, it is certain that in general they would not suffice to describe completely the state of the body if we had the power of noting every detail of its molecular structure.

Using theorems due to Thomson and Tait and to Larmor respectively, Prof. J. J. Thomson shows that the second difficulty may be overcome if the co-ordinates of the values of which we are ignorant do not enter into the expressions for the kinetic energy of the system. It then, however, becomes necessary to modify the Lagrangian function, but this new form is such that when it is expressed in terms of any variable quantities and their "velocities" they satisfy the mathematical condition to which a true geometrical co-ordinate and its velocity are subject. If L′ is the modified Lagrangian function, and q any one of a series of quantities, $q_1, q_2, \ldots$, in terms of which and of their velocities it can be expressed, then—

$$\frac{d}{dt} \cdot \frac{dL'}{d\dot{q}} - \frac{dL'}{dq} = 0.$$

The term co-ordinate is thus used by Prof. Thomson in the generalized sense of any quantity in terms of which and of its velocity the modified Lagrangian function can be expressed, and he assumes that as far as the phenomena under consideration are concerned the state of a body may be described by four different types of co-ordinates. These specify (1) the position in space of any bodies of finite size which may be in the system; (2) the strains in the system; (3) its electrical, and (4) its magnetic state.

The most general expression for the Lagrangian function is then formed. It may contain terms of various kinds. Prof. Thomson goes through them one by one, determines what the physical consequences of the existence of each would be, and if these are found to be contrary to experience concludes that the term in question does not exist.

Thus, for instance, it can be shown that if there were a term containing a product of the velocities of a geometrical and an electrical co-ordinate, an electrical "current would produce a mechanical force proportional to its square, so that the force would not be reversed if the direction of the current was reversed." As this and other similar deductions are all opposed to experience, no such term can exist.

A similar method is applied to the coefficients of the terms which are shown to be possible. Thus a term exists which contains the squares of the velocities of the geometrical co-ordinates. It corresponds to the expression for the ordinary kinetic energy. Prof. Thomson inquires whether the kinetic energy depends only on the geometrical co-ordinates, or whether it also varies with the electrical state of the various members of the system. The answer is given by means of an investigation of his own (*Phil. Mag.*, April 1881), in which he has shown that the kinetic energy of a small sphere, of mass m, and radius a, charged with e units of electricity, and moving with a velocity v, is—

$$\left\{\frac{1}{2} m + \frac{2}{15} \frac{\mu e^2}{a}\right\} v^2,$$

where μ is the magnetic permeability of the dielectric surrounding it. The effect of the electrification is therefore the same as if the mass had received an increment, which, however, numerical calculation shows is too small to be observed. It is, nevertheless, important that the mutual relationship between ordinary kinetic energy and electrification should be recognized, as it follows that the speed with which electrical oscillations are propagated across any medium will be diminished by the presence of conductors moving about in it. "Thus, if the electromagnetic theory of light is true, the result we have been discussing has an important bearing on the effect of the molecules of matter on the rate of propagation of light."

It would take too long to follow the author in detail through the interesting discussion which is pursued on these lines. Another example must therefore suffice. The specific inductive capacity of a dielectric depends upon the strain, and it follows that the distribution of stress which Maxwell supposes to exist in the electric field is supplemented by another, which is due to the relation between inductive capacity and strain. Maxwell's distribution will be the same for all dielectrics, but Quincke has shown that though most dielectrics expand when placed in an electric field, the fatty oils contract. In these cases the effects of what may be called the supplementary distribution are contrary to, and greater than, those produced by Maxwell's stress.

Phenomena which depend on temperature are specially discussed, and an interesting conclusion with respect to thermo-electricity may be noted. It is that from the heat developed by a current at a junction of two dissimilar metals we can derive information as to that part only of the electromotive force which depends upon the temperature. Hence the Peltier effect can throw no light upon the absolute difference of potential between two different metals.

A chapter is devoted to the calculation of "the Lagrangian function in the simplest case, when the body is in a steady state, when it is free from all strain except that inseparable from the body at the temperature we are considering, and when it is neither electrified nor magnetized." Two forms are found, which hold for the gaseous and the liquid or solid states respectively. The general principle is also laid down, that, "when the physical environment of a system is slightly changed, and the consequent change in the mean Lagrangian function increases as any physical process goes on, then this process will have to go on further in the changed system before equilibrium is reached than in the unchanged one, while if the change in the mean Lagrangian function diminishes as the process goes on it will not have to proceed so far."

As an example of this we may take the effect of a charge of electricity on the vapour-pressure of a liquid. If a spherical drop, of radius a, surrounded by a medium of specific inductive capacity K, is charged with e units of electricity, its potential energy is increased by $e^2/2Ka$, and thus electrification changes the mean Lagrangian function by the amount $-e^2/2Ka$. Prof. Thomson quotes experiments by Blake to prove that when an electrified liquid evaporates the vapour is not electrified, so that the charge e is unaffected by evaporation, while the radius a of course diminishes. On the whole, then, evaporation algebraically diminishes the term $-e^2/2Ka$, and therefore it will not proceed so far as before the liquid was electrified. Thus electrification diminishes the vapour-tension by an amount which is limited by the insulating power of the air. The maximum effect is about equal in magnitude, though opposite in sign, to that due to a curvature of a quarter of a centimetre. The suggestion is made that we should therefore expect an electrified drop of rain to be larger than an unelectrified one, so that this effect may help to produce the large drops of rain which fall in thunderstorms. The principle also leads to the conclusion that the density of saturated aqueous vapour in the presence of air is greater than if no other gas is present, and thus, apart from other causes, rain-drops would form more easily when the barometer is falling than when it is rising.

The properties of dilute solutions are discussed at length, and the Lagrangian function is calculated in accordance with the views of Van 't Hoff on the assumption that the molecules of a salt in a dilute solution behave as though they were in the gaseous state.

The results obtained cannot be considered favourable to the view that the effects of solution are capable of being stated in such simple terms. Röntgen and Schneider's experiments on the compressibility of saline solutions prove that the decrease in the compressibility is sometimes more than a hundred times greater than that calculated on the above assumptions. The author also points out that the rise in the osmometer, which is explained as due to the pressure of the dissolved salt, may be capable of other interpretations, and that at present the indications of the instrument must be considered ambiguous.

Enough has perhaps been said to give an idea of the method and scope of Prof. J. J. Thomson's work.

It is possible that some of the experimental results which are quoted require fuller confirmation than they have as yet received, but if the work is regarded as a text-book of mathematical physics this is a very minor defect. The author has developed a method of wide scope, and it is important that its applications should be fully illustrated, even if the data assumed are not in all cases unexceptionable.

The book literally bristles with novel suggestions and points of interest. An explanation of the fact recently discovered by Mr. Shelford Bidwell, that iron becomes shorter when the magnetizing force is very great; the effect of surface-tension on electromotive force; chemical action in thin films; the effect of a neutral gas on dissociation—these are some of the subjects, in addition to those which have already been mentioned, upon which we light on turning over the pages haphazard.

That it will make the study of physics and chemistry easier is only in one sense true. *Nihil tetigit quod non ornavit* may, as applied to Prof. J. J. Thomson, be freely translated, that he hardly mentions any law of physics except to complicate it with correction terms.

From a more serious point of view, however, it is difficult to over-estimate the value of the establishment of the less obvious connections between phenomena.

On many points, such as Quincke's and Bidwell's observations on the changes of magnitude produced in the electric and magnetic fields respectively, experiment needed the support of theory, and Prof. J. J. Thomson points out causes to which the observed effects may be due. Almost daily, conscientious experimentalists are spending time and ability in the detailed examination of facts which they cannot explain, and which they can only hope to explain by the most minute investigations. In the cases just mentioned the labour was well spent, but in others it is practically thrown away in the attempt to pierce a labyrinth the clue to which can be found only by mathematics. Prof. J. J. Thomson's book ought to be carefully studied by all physicists, and especially investigators who have discovered what they believe to be a new fact. In many cases it will suggest possible explanations which may prevent long and wearisome groping in the dark.

The author is to be warmly congratulated on his work, which is an achievement of a high order, and which will add to his already great reputation as a mathematical physicist.

RECENT WORKS ON ORNITHOLOGY.

Argentine Ornithology. By P. L. Sclater, M.A., F.R.S., &c., and W. H. Hudson, C.M.Z.S. Vol. I., pp. i.–xvi., 1–208, pls. i.–x. (London: R. H. Porter, 1888.)

British Birds: Key List. By Lieut.-Colonel L. Howard Irby. Pp. 1–58. (London: R. H. Porter, 1888.)

Birdsnesting and Bird-skinning: A Complete Description of the Nests and Eggs of Birds which breed in Britain. By Edward Newman. Second Edition. Revised and re-written, with directions for their collection and preservation; and a chapter on Bird-skinning, &c. By Miller Christy. Pp. i.–xii., 1–138. (London: T. Fisher Unwin, 1888.)

DR. SCLATER AND MR. HUDSON have combined their forces to produce one of the best books ever written on South American ornithology. Each is a master of his own portion of the subject, for no one is better acquainted with neotropical ornithology than Dr. Sclater, and Mr. Hudson has been known for many years as one of the best living observers of the habits of birds in the field. The scheme of the book, therefore, leaves nothing to be desired, and the whole of the "get-up," as regards paper, print, and illustrations (the latter a matter of course when Mr. Keulemans is the artist), is about as good as it is possible to be, and reflects the greatest credit on the publisher.

One of the most interesting features of the work will doubtless be the introduction, which will appear in the second volume, when it will be possible to form some accurate notion of the relations of the avifauna of the Argentine Republic with that of the neighbouring States, a comparison which will doubtless be of importance to all naturalists who are interested in the somewhat complicated natural areas of the neotropical region. At present the genera and species peculiar to the region treated of by the authors seem to be few in number, and they would appear to be limited to the more western portions of the country, especially the district of Tucuman.

It would be easy to give many extracts from Mr. Hudson's charming writings on the habits of the birds, with the life-history of many of which he is as familiar as we are in England with that of many of our British birds, while his travels have enabled him in many instances to give an account of species both in their summer and winter homes. To any naturalist visiting Argentina this book will be of the highest value, the descriptions given by Dr. Sclater being short and concise, but sufficient for the identification of species, while he is to be congratulated also on the success with which he has contrived to attach an English name to each bird. Everyone who has tried to do this, when writing on exotic birds, knows how difficult it is to invent English titles for species which have no counterpart in European nomenclature; and we must acknowledge that the names are a great improvement on some of the zoology "as she is taught" at our Zoological Gardens. Should some of the names bestowed upon animals in the "Zoo" ever be adopted in general works of travel, we might expect to find such truthful anecdotes as the following:—

"The insolent behaviour of one of the animals considerably annoyed us, from its persistent habit of making 'long noses' at us. On shooting a specimen we discovered that it was a Rude Fox (*Canis rudis*)," &c., &c.

"Some interesting little creatures now came in sight, dancing, apparently in perfect time, across the glade. They proved to be Pleasant Antelopes (*Tragelaphus gratus*)," &c., &c.

"Just as I was emerging from a thicket I managed to trip over something which brought me heavily to the ground. I fancied that I had fallen over a tree-stump, but on careful examination, it proved to be an Inconvenient Curassow (*Crax incommoda*) which had somehow got in my way," &c., &c.

In his useful little work, a "Key List to British Birds," Colonel Irby has supplied a real want—a handy pocket-book, giving just the diagnostic characters of every species. It is a desirable supplement to the "List of British Birds" published by the British Ornithologists' Union, which dealt with the nomenclature of the various species, but which might also with advantage have contained diagnoses, such as Colonel Irby's industry has now supplied.

What Colonel Irby has done for the birds, Mr. Miller Christy does for the eggs of British birds, and it is certain that with this little work in his hands the young student can gain a very good idea of the eggs which are likely to be met with in England. The call for this second edition of the late Mr. Newman's work shows apparently that there are a good many egg-collectors in this country, notwithstanding the prohibitions of an Act of Parliament; nor can we state with truth that there is any falling off in the number of students of the egg-collection in the British Museum since the Wild Birds Preservation Act became law. To the chapter on bird-skinning we would add a practical hint that before commencing operations a tiny wisp of wool should be inserted into the palate of the specimen. This greatly prevents the risk of discharge from the nostrils, and saves many a skin from being draggled and spoilt. The American method of enveloping the prepared skin in wadding is also far preferable to our method of fastening a paper band round the specimen.

R. BOWDLER SHARPE.

OUR BOOK SHELF.

Mechanics. By Edward Aveling, D.Sc. (London: Chapman and Hall, Limited, 1888).

THIS is the first of four treatises on mechanics and experimental science, published to meet the requirements of candidates in the matriculation examination of London University. The volume before us contains a great number of numerical examples and exercises for students, and twenty pages are devoted to specimen examination